Designing Optimal Sampling Networks, Fixed and Adaptive for Ocean Forecast Modeling

Paola Rizzoli, P.I.
Dept. of Earth, Atmos. & Planetary Sci.,
MIT, 54-1416, 77 Massachusetts Ave. Cambridge, MA 02139
Phone: 617-253-2451 Fax: 617-253-4464 Email: rizzoli@mit.edu

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LONG TERM GOAL

The overall long term goal is to develop innovative, practical and efficient methodologies for the design of fixed and adaptive oceanic platforms, eulerian and lagrangian, such as fixed moorings, profiling moorings, gliders, drifters, AUVs.

OBJECTIVES

The main objective is to develop this methodology for the Gulf of Maine/Georges Bank (GM/GB) region where an integrated model system has been developed at the University of Massachusetts at Dartmouth centered around the Finite- Volume Coastal Ocean circulation Model (FVCOM).

APPROACH

The technical approach will be to test the available data assimilation packages, i.e. Reduced Rank Kalman Filter (RRKF); Ensemble Kalman Filter (EnKF); Ensemble Square Root Kalman Filter (EnSRF) and the Ensemble Transform Kalman Filter (ETKF) in the idealized test-cases outlined in the report. Successively, the filters will be adapted to FVCOM in the GM/GB configuration for coastal circulation prediction and adaptive sampling studies.

WORK COMPLETED

See following pages.

RESULTS

See following pages.

IMPACTS/ APPLICATIONS

The potential future impacts of adaptive sampling in an oceanographic context, where they are still non-existent, will be comparable to the enormous impacts it has had in meteorology.

RELATED PROJECTS

None

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RESULTS

The P.I. and her Postdoctoral Associate, Dr. Jun Wei, have continued the collaboration with Prof. Chen and his group at the University of Massachusetts at Dartmouth. In the context of this collaboration, Dr. Wei has adapted three Kalman filters packages developed at MIT by the P.I. and her collaborators to the Finite Volume Coastal Ocean Model (FVCOM) developed by Prof. Chen and used to simulate and predict the circulation and properties distributions in the Gulf of Maine. The three packages comprise:

1) Reduced Rank Kalman Filter (RRKF) (Buehner and Malanotte-Rizzoli, 2003; Buehner et al., 2003);

2) Ensemble Kalman Filter (EnKF) (Zang and malanotte-Rizzoli, 2003);

3) Ensemble Square Root Kalman Filter (Lyu et al, 2007a);

4) Ensemble Transform Kalman Filter (ETKF) used to design adaptive observations (Lyu et al.,2007b).

After a first proof-of-concept application to three idealized configurations (Chen et al, 2007, submitted to JGR, here attached), FVCOM has been adapted to the realistic configuration of the Northeast Channel of the Gulf of Maine where three current-meters moorings have been deployed providing one year long hourly data of temperature, salinity and horizontal velocity components. Fig 1 shows the geographic configuration of the Northeast Channel with the location of the three moorings and the depths of the current meters. Fig 2 shows the variable finite-volume domain used in the simulations with the number of observations and the dimension of the state vector.

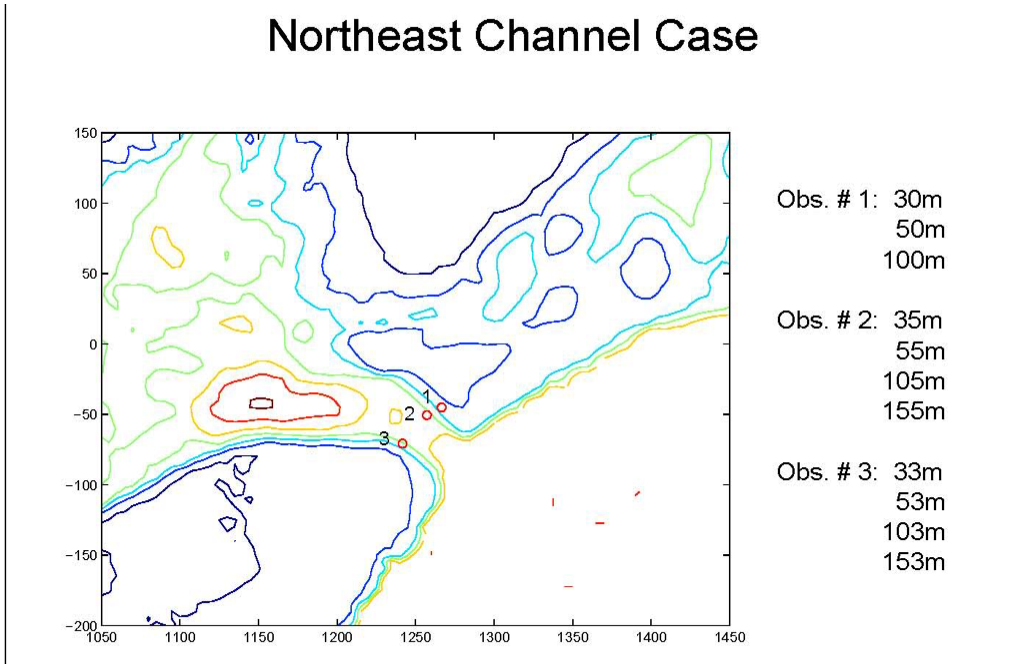

Fig 1. The geographic configuration of the Northeast Channel with the location of the three moorings and the depths of the current meters.

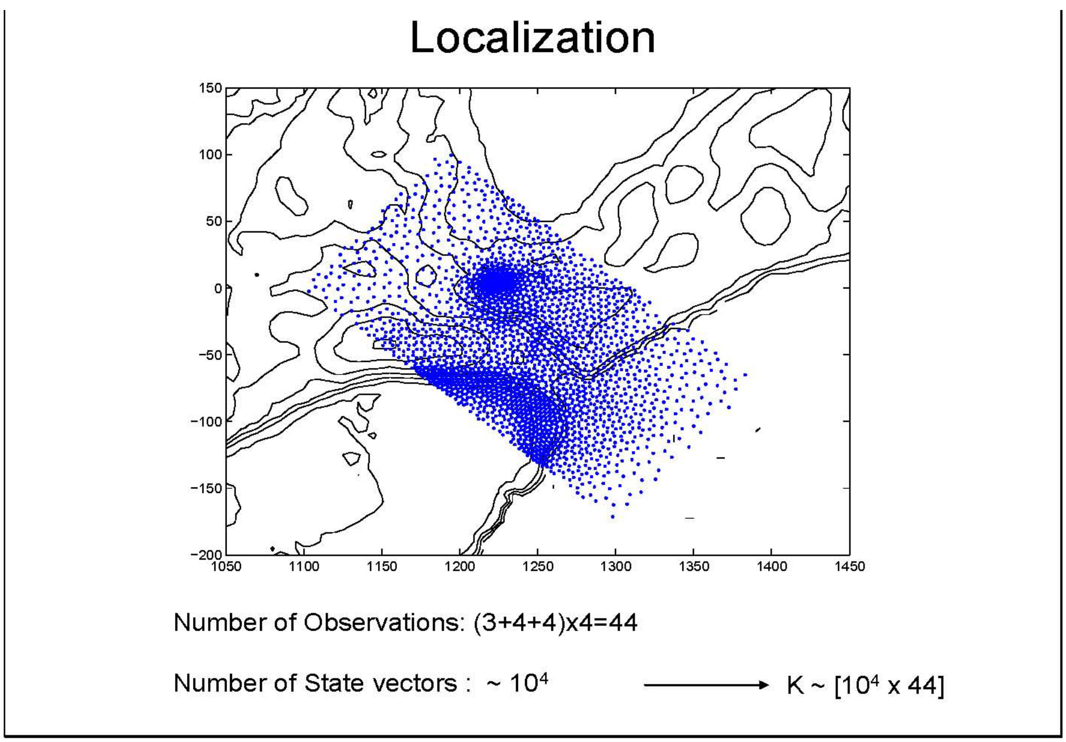

Fig 2. The variable finite-volume domain used in the simulations with the number of observations and the dimension of the state vector.

The Northeast Channel is the major passage connecting the basins of the Gulf of Maine and the slope water of the Northwest Atlantic Ocean. The transport crossing the channel, the deep inflow water on the northeast side of the channel and the outflow on the southwest side, play an important role in controlling the cyclonic circulation in the gulf.

Fig. 3 shows the experimental set-up of the Ensemble Kalman filter with the objectives, i.e. to assess the Filter performance changing the assimilation frequency, the time scale and the ensemble size. These preliminary simulations were carried out with 20 members in the ensemble generated from previous model fields.

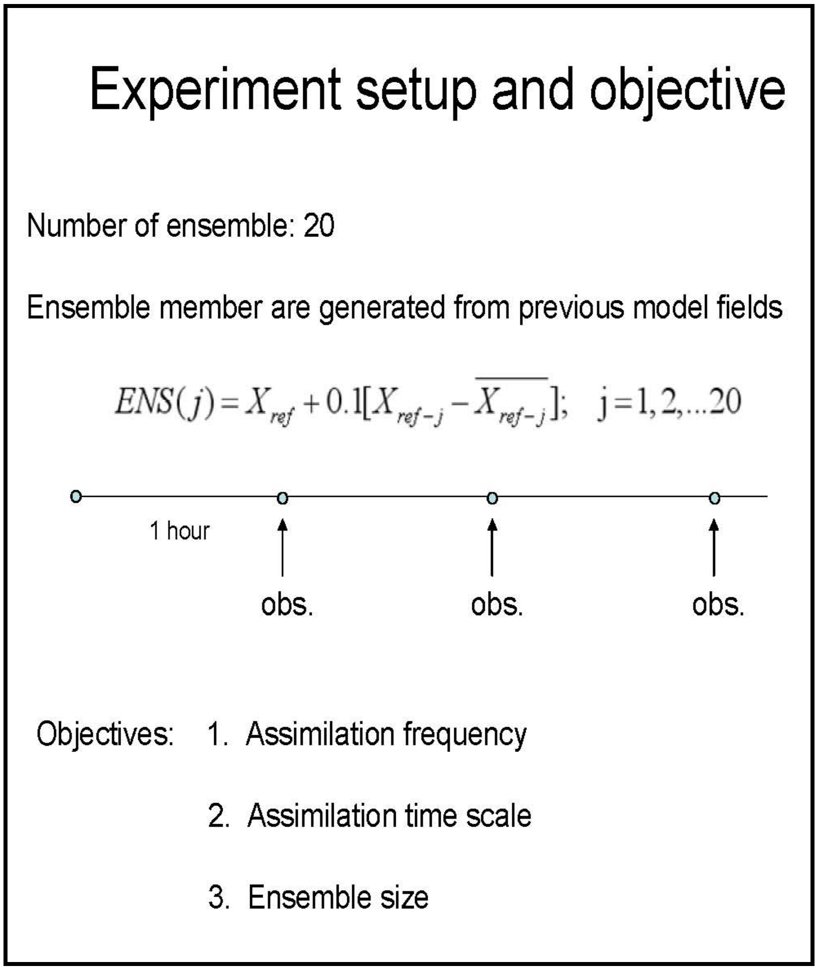

Fig. 3. The experimental set-up of the Ensemble Kalman filter with the objectives

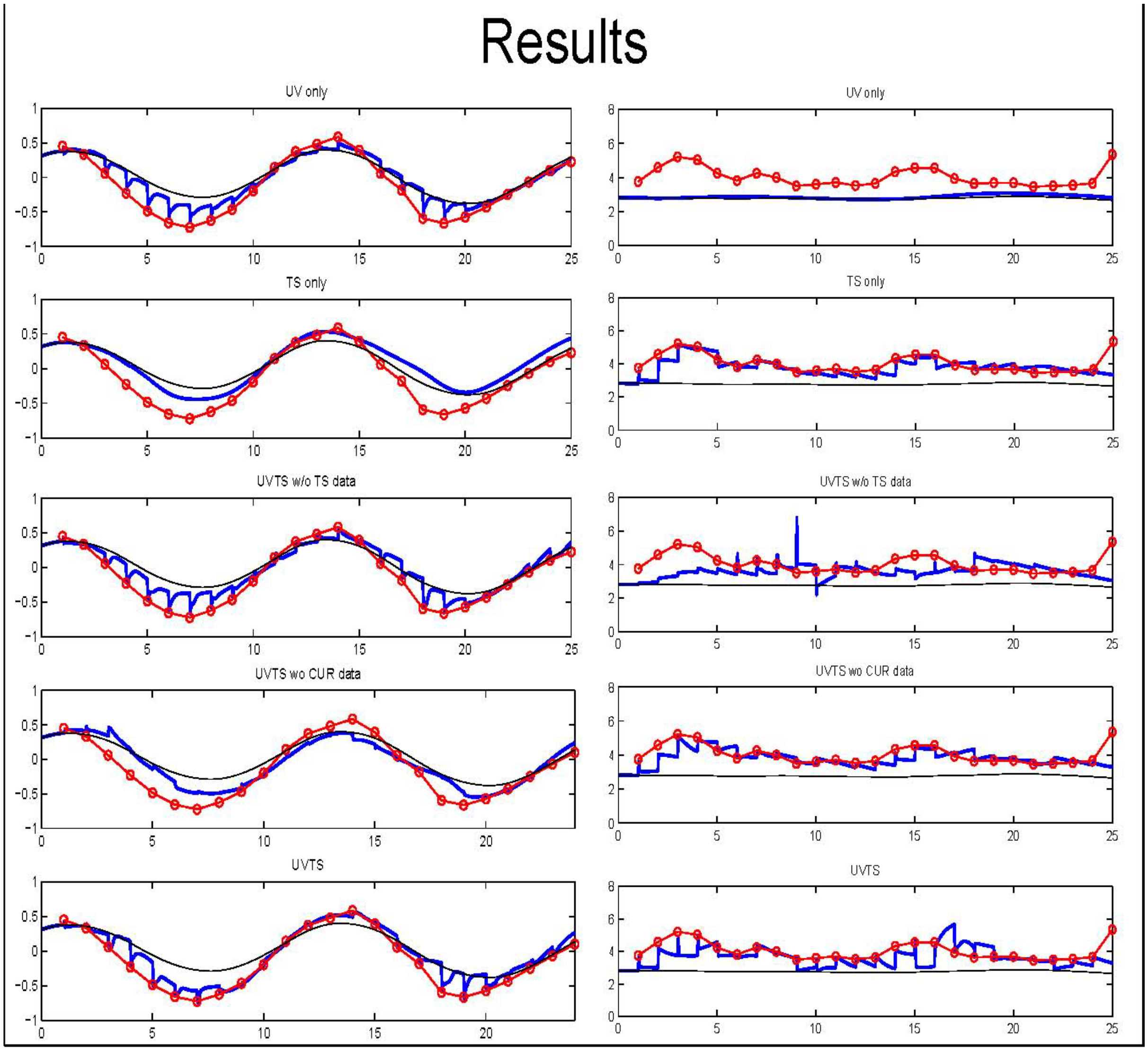

Fig .4 An example of these preliminary results.

The left columns show the v-velocity component at 30 m. depth and at observation site 1 (Fig.1). The right columns show the temperature again at 30 m. depth at site 1. The Black lines indicate the model simulations without assimilation. The red lines are the observations with hourly data shown as circles. The blue lines are the results of the ensemble assimilations at hourly interval. The titles of the various panels indicate the type of assimilation. In the upper panels only (U,V) velocity components were assimilated and updated; in the second panel from the top only (T,S) observations; in the third panel all (U,V,T, S) were updated using only (T,S) data; in the fourth panel again all variables were updated using only velocity data; finally, in the bottom panel all the variables were assimilated and updated. It is evident that velocity data only are quite ineffective in reproducing the temperature evolution and the assimilation is identical to the control model run (upper right panel). Similarly (T, S) data are ineffective in reproducing the V-component evolution (left panel, second from the top). As expected, the best results are obtained when assimilating and updating all the variables, bottom panels. Further experimentation is in progress and we envision the submission of a second paper by the end of the year.